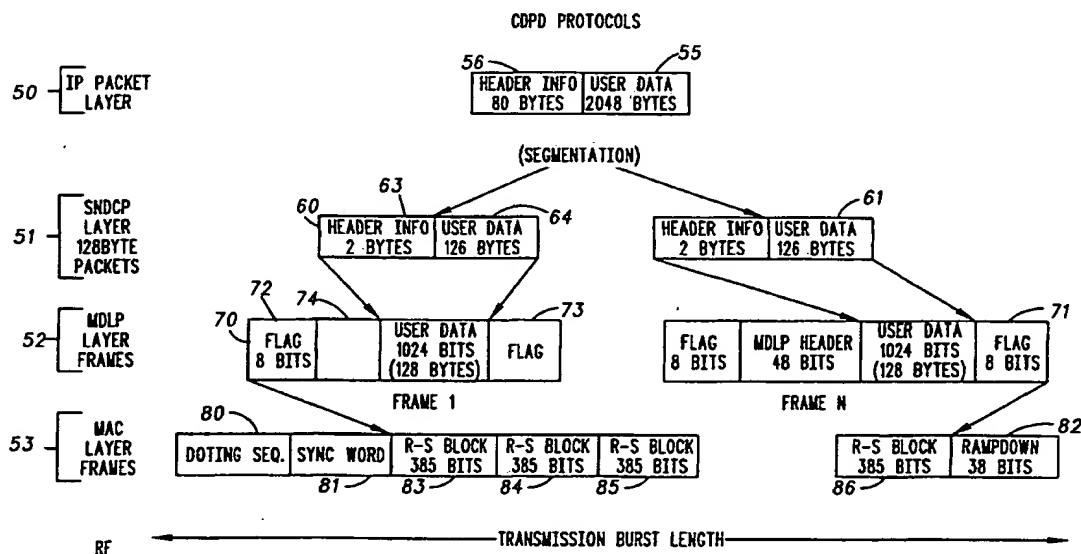




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>H04J 3/24</b>		A1	(11) International Publication Number: <b>WO 99/18685</b>
			(43) International Publication Date: 15 April 1999 (15.04.99)
(21) International Application Number: PCT/US98/16152		(81) Designated States: AU, CA, CN, DE, FI, GB, IL, SE.	
(22) International Filing Date: 31 July 1998 (31.07.98)		Published With international search report.	
(30) Priority Data: 08/942,831 2 October 1997 (02.10.97) US			
(71) Applicant: MOTOROLA INC. [US/US]; 1303 East Algonquin Road, Schaumburg, IL 60196 (US).			
(72) Inventors: ALFANO, Nicholas, P.; 3424 West 6th Avenue, Vancouver, British Columbia V6R 1T3 (CA). FRASER, Cameron; 4020 Brockton Crescent, N. Vancouver, British Columbia V7G 1E6 (CA).			
(74) Agents: HAAS, Kenneth, A. et al.; Motorola Inc., Intellectual Property Dept., 1303 East Algonquin Road, Schaumburg, IL 60196 (US).			

(54) Title: DATA COMMUNICATION METHOD AND APPARATUS FOR INCREASING THROUGHPUT BASED ON QUALITY OF COMMUNICATIONS CHANNEL



## (57) Abstract

Data is communicated over a communications channel such as a CDPD or GSM channel by formatting data for transmission into blocks (83-86) of data with error coding, formatting the blocks of data into transmission bursts (e.g. burst 88) with burst level overhead signaling, measuring a change in quality, e.g. RSSI, of the communications channel and adjusting the proportion of blocks of data to burst level overhead signaling according to the change in quality of the channel to increase the throughput when the channel quality is good and make the communication more robust when the channel quality is not so good.

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DATA COMMUNICATION METHOD AND APPARATUS FOR INCREASING THROUGHPUT  
BASED ON QUALITY OF COMMUNICATIONS CHANNEL

Field Of The Invention

5           This invention relates to a method of data communication in bursts of data over a communications channel, such as a radio channel and it relates to apparatus for performing such a method.

Background Of The Invention

10           Data communications systems generally operate according to a logical hierarchical architecture such as the well established OSI model. In such an architecture, messages or files from a high level application are formatted into packets or packet fragments in a transport or network layer  
15           and the packets or packet fragments are sent over the communications channel as one or more bursts of signal. Typically upon transmission, error coding is added to the source data in one or more of the intermediate levels of the architecture, and typically, an  
20           acknowledgement request (ARQ) protocol is used whereby the recipient acknowledges complete or partial receipt of a burst of signals or negatively acknowledges failure to receive a burst of signals. The error coding can be used by the ARQ protocol to ascertain whether a burst of signal is correctly received

25           As data is transmitted down the layers of protocol, each layer of a hierarchical communications architecture adds some degree of overhead signaling in the form of headers containing Protocol Control Information to data received from a higher level. There is a need generally to minimize the amount of additional signaling added to the data while achieving a robust and reliable communications link in varying  
30           conditions

          In the past, efforts have been targetted at minimizing the proportion of error coding to user data that is added in transmission. A high proportion of error coding results in greater reliability of first time reception of a message but reduces the effective bandwidth for raw data.  
35           At lower levels of error coding more of the bandwidth is available for raw

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data but reliability of reception decreases over a noisy channel and requests for retransmission increase. This in turn reduces the efficiency of usage of the channel.

There is a need for a method and apparatus for communicating data over a communications channel in a manner that optimizes throughput of data for the channel conditions.

These and other problems and disadvantages in prior art communications systems are overcome by the present invention, preferred embodiments of which are now described, by way of example only, with reference to the drawings.

#### Brief Description of the Drawings

FIG. 1 is a sketch diagram of a cell of a cellular communications system with remote terminals in accordance with the invention.

FIG. 2 is a protocol layer diagram illustrating a first embodiment of the invention in the context of a cellular digital packet data (CDPD) system.

FIG. 3 is a diagram illustrating transmission bursts in a second embodiment of the invention in the context of a GSM packet radio system (GPRS).

FIG. 4 is a circuit diagram illustrating circuit details of a communications unit (either a base station or a remote terminal) for implementation of either the first or second embodiment of the invention.

#### Detailed Description of the Drawings

Referring to FIG. 1, a cell 10 of a cellular radio system, which can be a CDPD or GSM radio system is illustrated. It will be understood that the cell 10 can equally be a stand-alone site of a trunked radio system. At a central point in the cell 10 is a base station 11 having a transceiver 12 and a controller 13. The transceiver 12 gives a received signal strength indication (RSSI) 15 to the controller 13 and exchanges data with the controller 13 over data lines 16.

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Also shown in the cell 10 in FIG. 1 are two remote units 20 and 21, each comprising a data terminal (22 and 24 respectively) and a data modem (23 and 25 respectively).

5 In operation, data communication takes place between the base station 11 and the remote units 20 and 21 in bursts. For a very short message, a single burst may be sufficient to carry the complete message. For a larger message, datagram or file, several bursts from a remote unit to the base station or from the base station to a remote unit may be necessary in order to transfer the complete message, datagram or file (generally  
10 referred to herein as a "message"). In the case of a large message, the message is packetized or fragmented and each packet or fragment of a packet is sent in a single burst (or a number of packets are sent in a single burst).

Accompanying a burst is a quantity of burst level overhead  
15 signaling. Typically, at a minimum, there is some acknowledgement request (ARQ) data such as data indicating the packet length and (on a return channel) there is an acknowledgement or a negative acknowledgement or a partial acknowledgement. The present invention recognizes that greater efficiency of use of the channel can be achieved by  
20 maximizing the proportion of burst level payload data (i.e. user data plus any error code or other high level overhead data) to burst level overhead signaling.

In accordance with the present invention, channel usage is increased or maximized by adjusting the proportion of data to burst level  
25 overhead signaling according to a change in quality of the channel. A change in quality can be measured by RSSI or by bit error rate (BER) or it can be inferred from the rate of return of negative acknowledgements (NACKs). Thus, in a high quality channel, advantage is taken of the good channel conditions by increasing the proportion of data to burst levels  
30 signaling for example by lengthening the bursts, and in poor channel conditions, the proportion of data is reduced, thereby making the data transfer more robust. An example of increased robustness is the requirement to acknowledge receipt of shorter bursts with the result of reducing the rate of retransmission requests per burst and reducing the  
35 size of retransmissions.

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The invention will be described in greater detail in terms of a first embodiment in the context of a CDPD system. Referring to FIG. 2, a CDPD protocol is shown as comprising an internet protocol (IP) packet layer 50, a subnetwork dependent convergence protocol (SNDCP) layer 51, or mobile data link protocol (MDLP) layer 52 and a medium access control (MAC) layer 53.

In operation, data from an application layer (not shown) above IP layer 50 is inserted into user data field 55 of the IP layer 50. The user data field is variable in length, from 1 to 64k bytes and a typical size is 2048 bytes. To this field is added a header 56 of 80 bytes. The IP layer packets are segmented into SNDCP layer packets 60, 61 of 128 bytes each. Each SNDCP layer packet comprises a 2-byte header 63 and a 126-byte user data field 64. SNDCP layer packets are inserted into MDLP layer frames 70, 71 etc., one packet per frame and to each packet is added front and rear flag fields 72 and 73 as well as 48 bit header field 74. The MDLP layer frames are block coded into Reed-Solomon blocks of 385 bits per block.

The Reed-Solomon (R-S) coding scheme can be variable or adaptive to channel conditions but is preferably fixed. I.e. a fixed proportion of error coding is added to the MDLP layer frames. A predetermined number M of blocks 83-86 of R-S coded data are formed together into a single transmission burst 88 and to these M blocks are added a dotting sequence 80 (in the case of a remote unit-to-base station transmission), a synchronization and 81 and a ramp down period 82 equal to 38 bits. The number M of R-S blocks in a burst is never greater than a predetermined parameter referred to as MAXBLOCKS.

The burst length in the MAC layers 53 has an upper limit and any excess of frames (not shown) in the MDLP layer 52 that cannot be inserted into a single MAC layer burst must be inserted into a subsequent MAC layer burst (not shown).

User data field 55 in the IP layer is variable in length and can theoretically be any size, but practically speaking, 64,000 bytes would be a very large packet. IP packets are typically 128 to 4096 bytes in length.

The parameter MAXBLOCKS sets the upper limit or the number of R-S blocks that can be transmitted during a single transmission burst. If a base station receives more than MAXBLOCKS continuous blocks in the

- 5 -

same burst, it exits its receive state and signals a decoding failure (see CDPD system specification Release 1.1, January 17, 1995 page 402-33 section 5.2.3.2). In existing systems, this parameter is fixed at system installation time and can only be adjusted manually. According to the present invention, this parameter is adjustable according to channel quality.

Channel quality can be measured in a number of ways. As an example, the base station 11 can receive R-S blocks from a remote unit 20 and, in decoding those blocks, it can measure a bit error rate. This is an indication of the quality of the channel between the base station 11 and the remote unit 20 and by reciprocity, it is generally assumed to equally represent the quality of the channel in both directions. Alternatively, NACK messages received from a remote unit can indicate the quality of the channel. It is preferred, however, that channel quality is measured by RSSI.

In the example of FIG. 1, transceiver 12 receives radio frequency (R.F.) signals from the remote units 20 and 21 and passes a demodulated signal (with or without decoding) to the controller 13. Transceiver 12 also provides controller 13 with a received signal strength indication (RSSI) on line 15. Controller 13 averages the RSSI value over time, giving an average RSSI for all bursts and therefore an average RSSI for all remote units in the coverage area, regardless of their distance from the base station 11 and regardless of intervening obstacles, reflections or interferences. (As an alternative, however, base station 11 measures RSSI values for individual remote units).

From the measured RSSI, base station controller 13 computes a MAXBLOCKS value. The value is preferably computed according to a predefined function but could be obtained from a look-up operation in a table stored in memory (not shown). Higher values of RSSI are mapped in such a table to higher values of MAXBLOCKS and lower values of RSSI are mapped to lower values of MAXBLOCKS. The relationship is not necessarily linear. The exact mapping is of no great significance. As an example, MAXBLOCKS is set to 80 blocks where the average RSSI is high and 48 blocks where the average RSSI is low, but these values do not represent extremes.

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The base station 11 transmits the MAXBLOCKS parameter in a special broadcast message to all remote units (e.g. using a broadcast address). On receipt of the broadcast message, each remote unit stores the new MAXBLOCKS parameter and overwrites any previously set  
5 MAXBLOCKS parameters.

Future transmission bursts sent by the remote units 20 and 21 are formatted into MAC layer frames so that the number of R-S blocks of data in a frame (and hence a burst) does not exceed the new value. Note that a remote unit can, of its own accord, set an upper limit on a burst size  
10 which is less than MAXBLOCKS. It may choose to do this if it senses an RSSI which indicates that it is particularly distant from the base station (or in a fade or shadow). It may also do this if it measures a high BER on the channel indicative of a source of noise in the vicinity of the remote unit.

As a modification of the above scheme, base station 11 sends  
15 individually selected values of MAXBLOCKS addressed to individual remote stations and selected according to a channel quality parameters measured for a given remote station-to-base station path.

As a result of the arrangement described above, when the channel quality is good (e.g. as indicated by a high RSSI from transceiver 12 to  
20 controller 13), the system takes advantage of the good channel by sending more blocks in a burst. Thus the proportion of used data (RS blocks 83, 84 etc.) to burst overhead data (dotting sequence 80, sync word 81, rampdown 82 and any reverse channel ACK) is increased, (i.e. the ratio of error coded data to burst level overhead signaling is increased) making the channel  
25 usage more efficient. Similarly, when the channel quality deteriorates, the ratio of error coded data to burst level overhead signaling is decreased by reducing the parameter MAXBLOCKS.

Referring now to FIG. 3, a second embodiment of the invention is described in the context of a GSM packet radio system (GPRS). FIG. 3  
30 shows a GPRS multiframe in an uplink 100 (ie. remote unit-to-base station) and a downlink 101 (ie. base station-to-remote unit). FIG. 3 shows that each of the uplink and downlink is formed of slots or bursts and an uplink physical radio channel 102 and a downlink physical radio channel 103 are shown illustrating that the uplink 100 is time-division  
35 multiplexed onto every 8th slot 110, 111, 112 etc. of the uplink physical



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radio channel 102. The downlink 101 is also multiplexed onto every 8th slot of the downlink physical radio channel 103.

In operation, a random access burst 120 is sent by a remote unit (eg. remote unit 20) on the uplink 100. There is typically an exchange of an allocation time slot 121 and a uplink time slot group (TSG) 122 (shown for simplicity as a single time slot), leading to an allocation being sent by a control downlink TSG 123 which allocates an uplink traffic TSG 125. There may be a further allocation time slot or TSG 126 allocating further traffic TSGs 128 and 130. Finally, upon receipt of an acknowledgment request and error connection as needed, further allocations (not shown) are made in the downlink 101 for transmission of an ACK during traffic downlink TSG 140 and a response during traffic uplink TSG 141. The figure is not to scale.

In accordance with the present invention the size of one or more of the time slot groups (TSGs) is adjusted in response to channel conditions. As an example, the size of the uplink TSG 125 is increased in downlink TSG 123 when the channel quality is good and decreased when it is bad. It can readily be seen that extending the size of uplink TSG 125 in good channel conditions can obviate the need for downlink TSG 126. This would be the case if uplink TSG 125 were expanded in size sufficiently, to include uplink TSGs 128 and 130. With such a modification, the efficiency of usage of the uplink channel is increased in good channel conditions. There are efficiency gains in usage of the downlink channel also by way of a reduction in time slot group overhead signaling and a reduction in acknowledgment request signaling.

Referring now to FIG. 4, elements of an example of a remote unit 20 in accordance with the present invention are shown. The construction and operation of other remote units (e.g. remote unit 21) are identical and need not be described separately.

The remote unit 20 comprises a transmitter 201 and a receiver 202, both coupled to a duplexer 203 and, through the duplexer, to an antenna 204. A synthesizer 205 is coupled to each of the receiver 202 and the transmitter 201. A demodulator 210 is coupled to receiver 202. A modulator 211 is coupled to the synthesizer 205. A logic unit 220 is coupled via data lines 221 and 222 to the demodulator 210 and modulator

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211, respectively, and is coupled by control lines 223 and 224 to the demodulator 210 and the receiver 202 and to the transmitter 201 respectively. A received signal strength indication (RSSI) line 212 passes from the receiver 202 to the logic unit 220, but this is optional. A control  
5 bus 226 is coupled between the logic unit 220 and the synthesizer 205. Logic unit 220 is shown, by way of example, as comprising an error decoding circuit 213 and an error coding circuit 214 and a burst formatter 234. It may additionally or in the alternative include an error detect circuit and an error check generating circuit (not shown) and a timing  
10 circuit 229.

Coupled to the logic unit 220 via a digital bus 228 is a processor 230. Coupled to the processor 230 is a random access memory (RAM) 231, a program memory in the form of electrically erasable programmable read-only memory (EPROM) 232, an operator interface 233 such as a keyboard  
15 and display and an I/O interface 235 connected to host data terminal 22.

In transmit operation, the processor 230 receives from the data terminal 22 a message or file for transmission. The processor 230 performs segmentation and fragmentation (if required). In the case of a CDPD context, processor 230 adds headers 63 in the SNDTCP layer and fields  
20 72 and 74 in the MDLP layer. Resultant frames are supplied by processor 230 to logic unit 220. In logic unit 220, error coding circuit 214 generates Reed-Solomon coded data blocks, and burst formatter 234 adds dotting sequence 80 and synchronization word 81 to each burst and timing circuit 229 controls the timing of outputting of the resultant transmission burst  
25 data to the modulator 211.

It will, of course, be appreciated that alternative arrangements can be provided. For example, processing at a higher layer than the physical layer can be performed by the logic unit 220. Alternatively, physical layer processing including the error coding can be performed by the processor  
30 230. Processor 230 and logic unit 220 can be integrated together in a single microcontroller or application specific integrated circuit.

The logic unit 220 passes the data of each resultant transmission burst to the modulator 211 bit-by-bit and provides a transmitter key-up signal on control line 224. The timing circuit 229 controls the timing of

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key-up of the transmitter 201, so that a transmission burst is transmitted at a selected time.

On the receiver side, bursts of data are received via the antenna 204 to the receiver 202 and demodulated by the demodulator 210 and passed to the logic unit 220. RSSI line 212 provides logic unit 220 with values of RSSI for the received signals.

In receive operation, error decoding circuit 213 performs error correction and optionally provides a bit error rate indication to logic unit 220. Corrected data is passed to the processor 230 for further processing. Where logic unit 220 is unable to verify a burst as validly received, the processor 230 is informed. Where a burst is not validly received, processor 230 generates a NACK response, which is sent via logic unit 220, modulator 211 and transmitter 201.

The processor 230 recombined packet fragments and packets for passing on to upper layers of the protocol, for presentation at the operator interface 233 or for outputting at the data terminal 22. As described the logic unit 220 performs physical layer processing, but higher layer processing can also be performed by logic unit 220, or physical layer processing (such as the error decoding function of error decoding circuit 213) can be performed by the processor 230. These details are not significant.

Instead of duplexer 203, an antenna switch can be used, allowing alternative receive and transmit modes, even on the same frequency. Logic unit 220 controls synthesizer 205 via control bus 226 to select appropriate frequencies for transmission and reception depending on the particular frequencies of the system and the modulation scheme and other aspects of the physical layer.

The structure of the base station transceiver 12 and its controller 13 is the same as the structure of the data modem 23, as illustrated in FIG. 4. With respect to transmission and reception of a single burst, the operation is the same. The base station transceiver 12 with its controller 13 operates to transmit bursts to many remote units. Because transmission can be continuous, a dotting sequence 80 is not necessary. In other respects the circuit-level operation is not significantly different from the operation of a remote unit. From time

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to time the controller 13 generates a burst length parameter responsive to the RSSI on line 15 or responsive to a bit error rate or some other indicator or combination of indications of channel quality and sends this in a special message to all remote units.

5           When receiving, the base station transceiver 12 with its controller 13 operates to receive bursts from many remote units.

Thus, a method has been described for communicating data in packets from a first radio unit 20 to a second radio unit 12, over a radio communications channel, comprising, at the first unit 20: formatting  
10       data for transmission into first blocks (e.g. blocks 83-86) of data with error coding to provide error coded data; formatting the first blocks of data into transmission bursts 88 or 125-130 with a first ratio of burst level overhead signaling to error coded data (e.g. data 81 in the case of CDPD and the ack/request in time slot group 130 or the burst 126 in the  
15       case of GPRS); transmitting the first blocks of data to the second radio unit 12; measuring, e.g. on RSSI line 15, a change in quality of the communications channel; formatting further data for transmission into second blocks (e.g. further blocks 83, 84 etc.) of data with error coding to provide error coded data; formatting the second blocks of data  
20       into transmission bursts with a second ratio of burst level overhead signaling to error coded data, adjusted with respect to the first ratio in response to the change in quality of the communications channel; and transmitting the second blocks of data to the second radio unit 12.

Preferably the measuring of the change in quality takes place at  
25       the second radio unit 12 and is communicated to the first radio unit 20, for example in the form of a maximum block parameter, but it will be understood that the measuring of change in quality can take place at the first radio unit 20.

In this way, the ratio of data to burst level overhead signaling  
30       can be maximized for given channel conditions and can be made dynamic according to channel quality.

It will be understood that the above description has been given by way of example only and that modifications of detail can be made by one skilled in the art without departing from the scope and spirit of the  
35       invention.

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We Claim:

1. A method of communicating over a communications channel,  
5 comprising:  
    formatting data for transmission into blocks of data with error coding;  
    formatting the blocks of data into transmission bursts with burst level overhead signaling;  
10      measuring a change in quality of the communications channel; and  
    adjusting a proportion of blocks of data to burst level overhead signaling according to the change in quality of the channel.
2. The method of claim 1 wherein the step of measuring a change in  
15 quality comprises measuring a received signal strength on the channel.
3. The method of claim 1 wherein the step of measuring a change in quality comprises measuring an error rate from blocks of data received over the channel.  
20
4. The method of claim 3 wherein the step of measuring a change in quality comprises measuring at a base station a quality parameter for a plurality of communications links.
- 25 5. The method of claim 1 wherein the step of measuring a change in quality comprises receiving a response to a transmission and inferring a change in quality from the response received.
- 30 6. The method of claim 1, wherein the step of adjusting comprises increasing the number of blocks of data in a transmission burst when an improvement in the quality of the channel is measured and decreasing the number of blocks of data in a transmission burst when a deterioration in the quality of the channel is measured.

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7. The method of claim 1 comprising a step of sending an allocation message from a first unit to a second unit over a forward channel and sending the transmission bursts from the second unit to the first unit over a reverse channel, wherein the step of adjusting the proportion of blocks of data to burst level overhead signaling comprises adjusting a number of blocks of data sent from the second unit to the first unit for a given size of allocation message sent from the first unit to the second unit.
8. The method of claim 1, wherein the communications channel is a time division multiplexed channel over which data is transmitted in time slots groups, wherein the step of adjusting the proportion of blocks of data to burst level overhead signaling comprises maintaining a predetermined degree of overhead signaling per time slot group and adjusting a time slot group size.
9. A communications unit adapted for communication over a communications channel comprising a channel quality indicator indicating a quality of the communications channel and a burst formatter for formatting bursts for transmission responsive to the channel quality indicator to adjust burst sizes according to channel quality.
10. A method of communicating data in packets from a first radio unit to a second radio unit over a radio communications channel, comprising, at the first radio unit:
- formatting data for transmission into first blocks of data with error coding to provide error coded data;
  - formatting the first blocks of data into transmission bursts with a first ratio of burst level overhead signaling to error coded data;
  - transmitting the first blocks of data to the second radio unit;
  - measuring a change in quality of the communications channel;
  - formatting further data for transmission into second blocks of data with error coding to provide error coded data;
  - formatting the second blocks of data into transmission bursts with a second ratio of burst level overhead signaling to error coded data, adjusted

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with respect to the first ratio in response to the change in quality of the radio communications channel; and  
transmitting the second blocks of data to the second radio unit.

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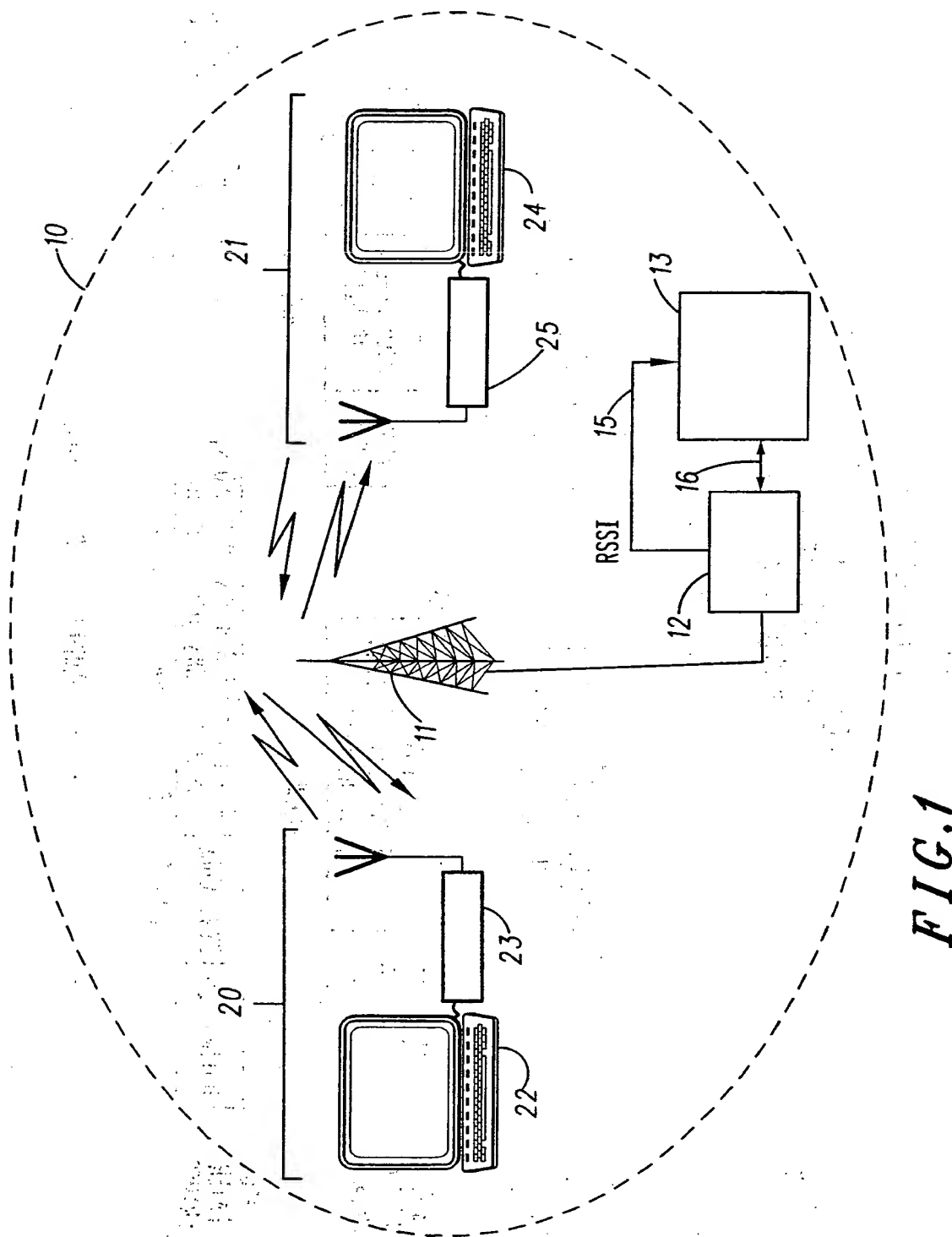


FIG. 1



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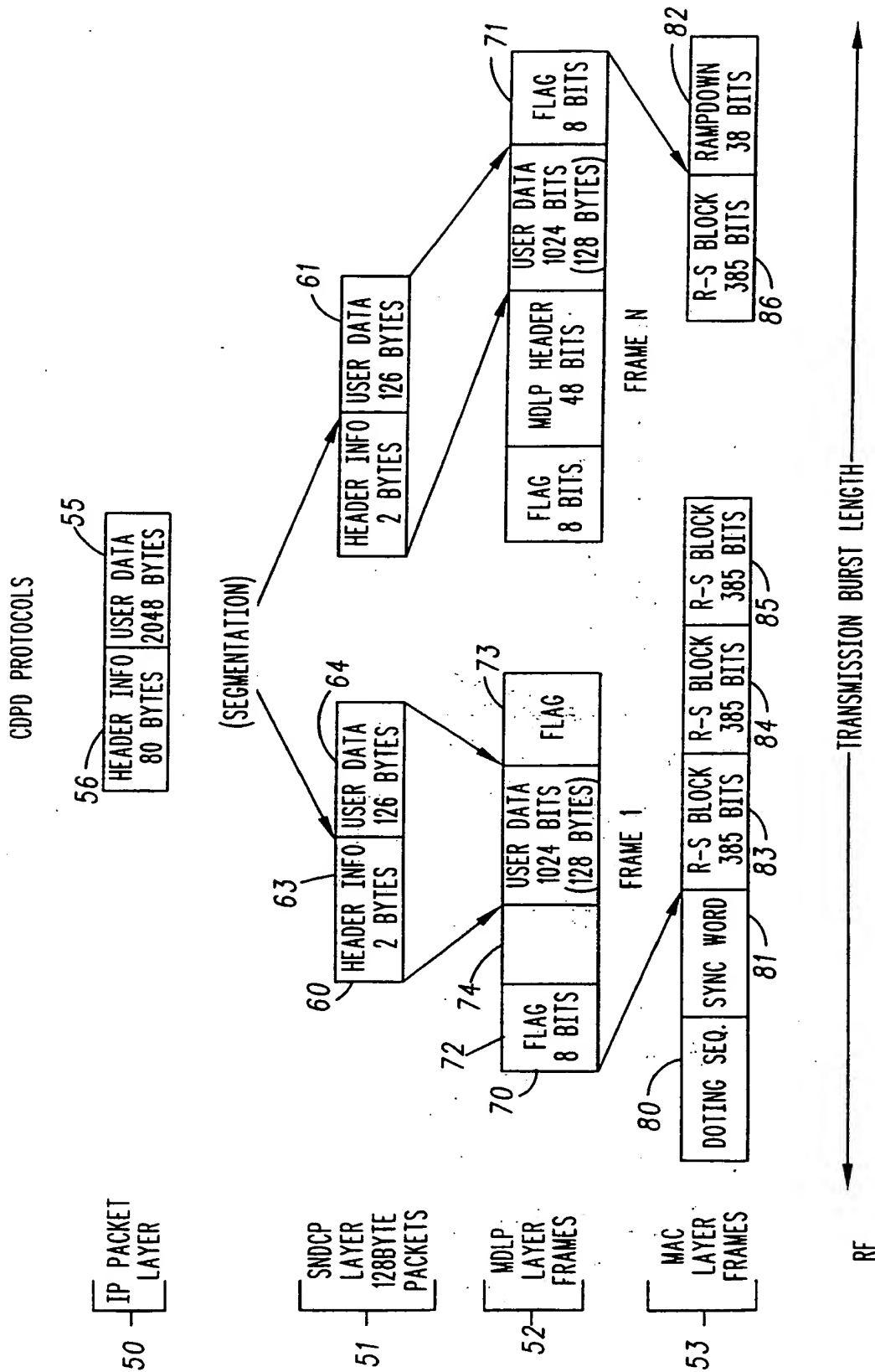
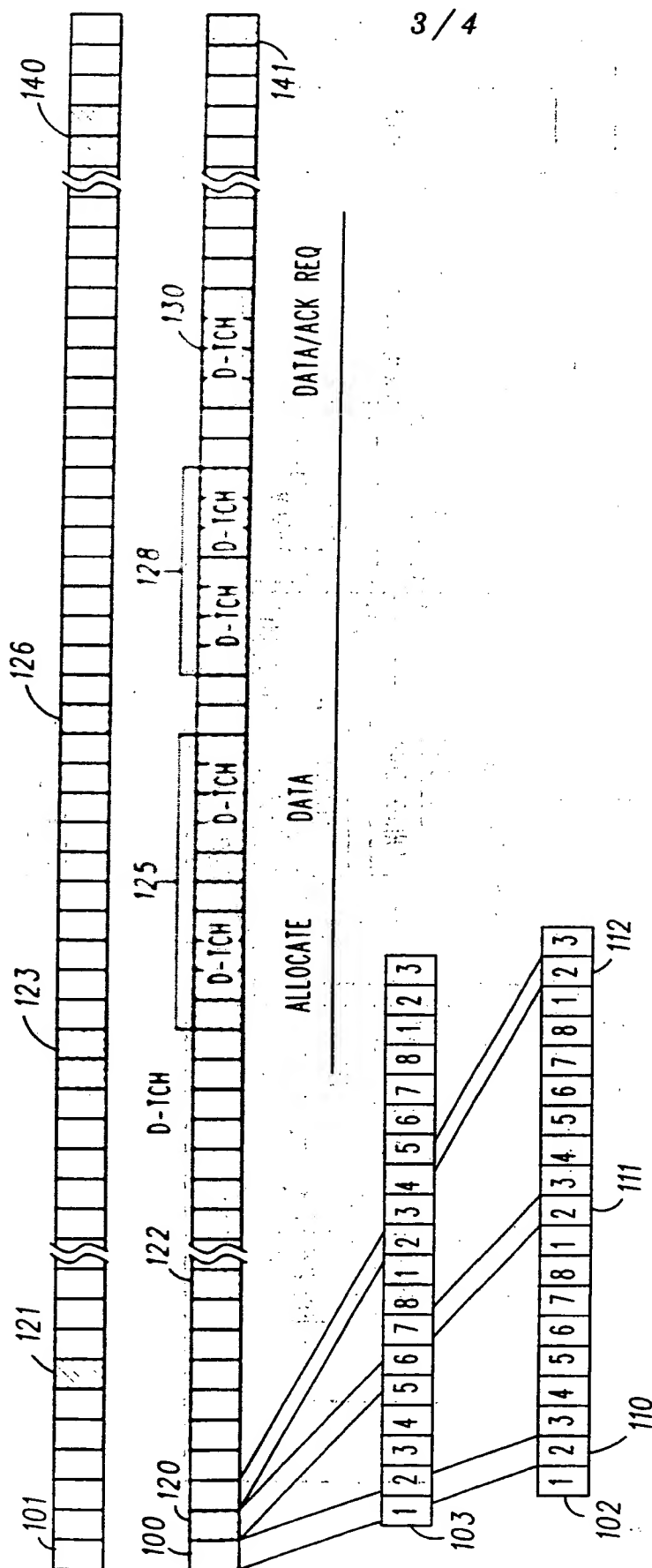


FIG. 2



**FIG. 3**

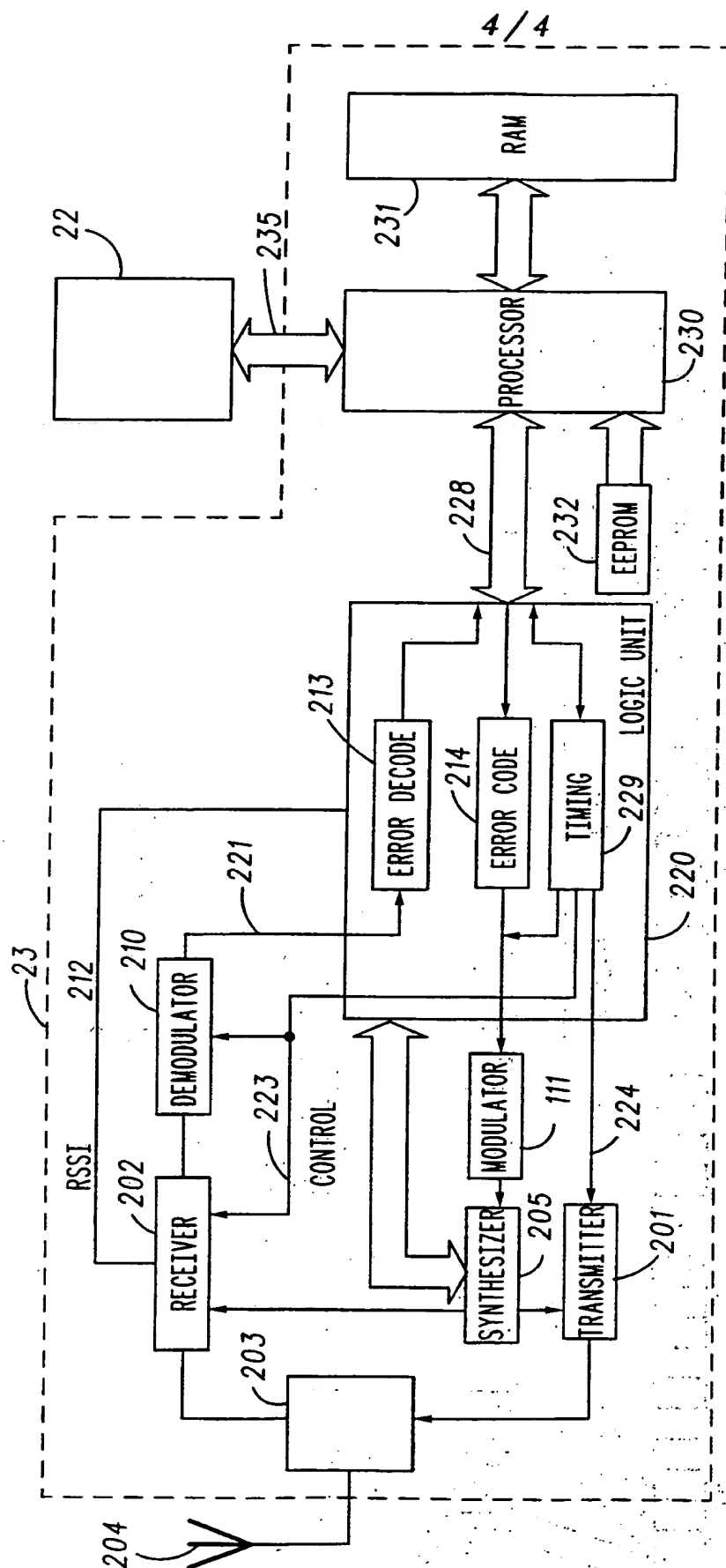


FIG. 4

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/16152

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H04J 3/24

US CL : 370/470; 371/5.5

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/470; 371/5.5; 370/471, 468, 476, 310, 328, 522, 332, 333, 252, 465; 455/67.1, 67.3; 371/37.01, 37.11, 48; 455/69, 72;

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

SEARCH TERMS: ADJUST? (5A) FRAME SIZE; CHANG? BURST SIZE

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,307,351 A (WEBSTER) 26 APRIL 1994 (26.04.94), col. 3, lines 25-33, col. 4, lines 14-26, fig. 3 and col. 6, line 68, col. 7, lines 1-2.	1-10
Y	US 5,537,395 A (ALLES et al.) 16 JULY 1996 (16.07.96), col. 3, lines 2-5, col. 1, lines 59-60, col. 6, lines 57-60, col. 5, lines 35-62, col. 4, lines 48-56.	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Authorized officer

CHI PHAM

Dian Smith

Telephone No. (703) 305-4378